Marine Stratus/Stratocumulus Experiment (MASE)

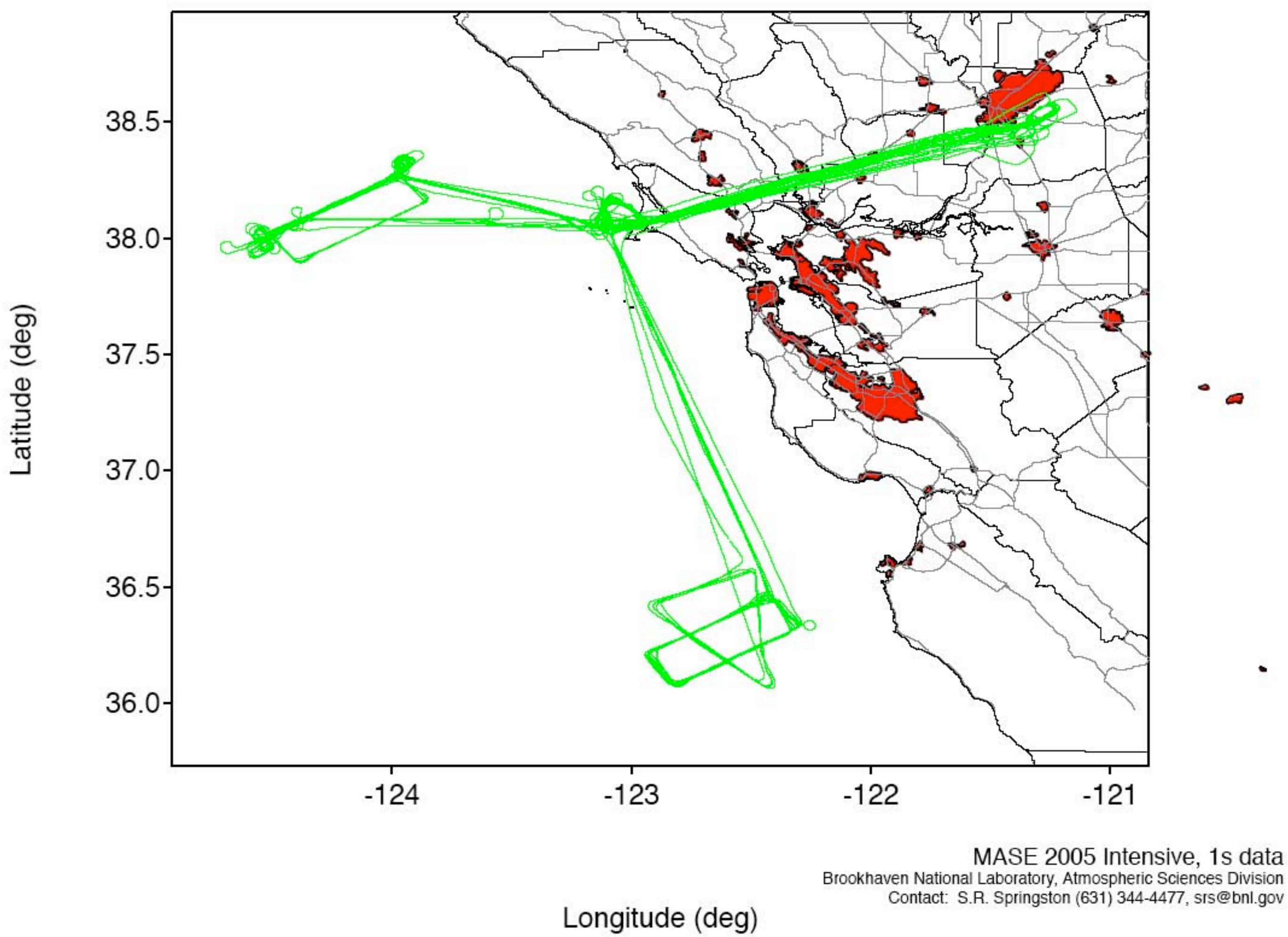
Objectives-

Use the low altitude marine stratus/stratocumulus clouds that commonly occur off the coast of Northern CA as a natural laboratory to examine-

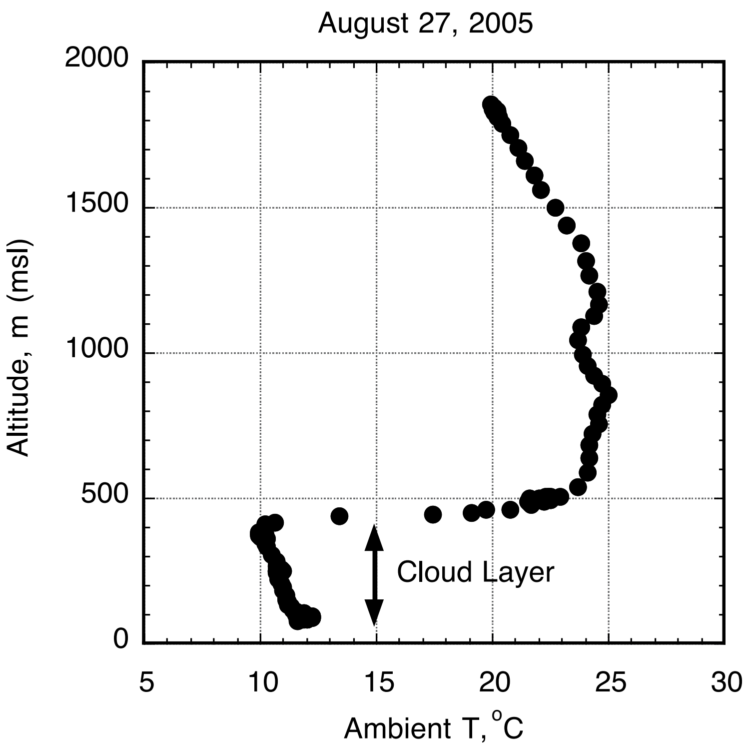
- ✓ ***The effects of aerosol loading and composition on cloud droplet microphysics. (First Indirect Effect)***

- ✓ ***The effects of cloud microphysics on the formation of drizzle in clouds.(Second Indirect Effect)***

FLIGHT TRACKS

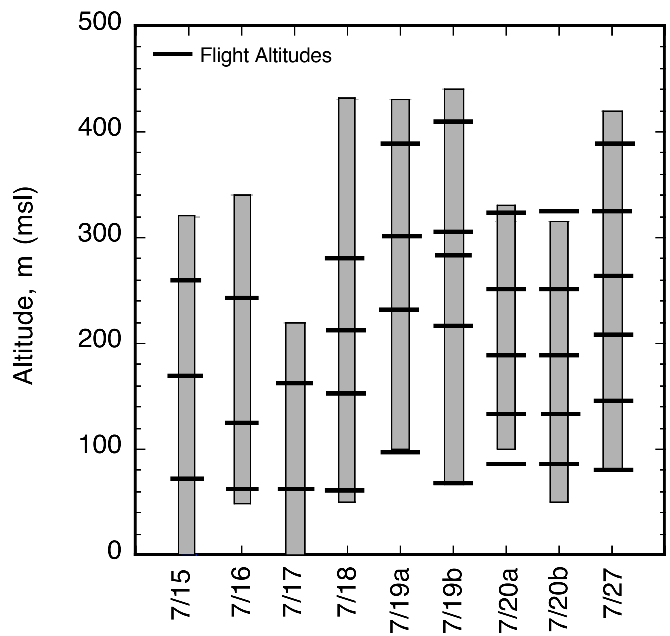


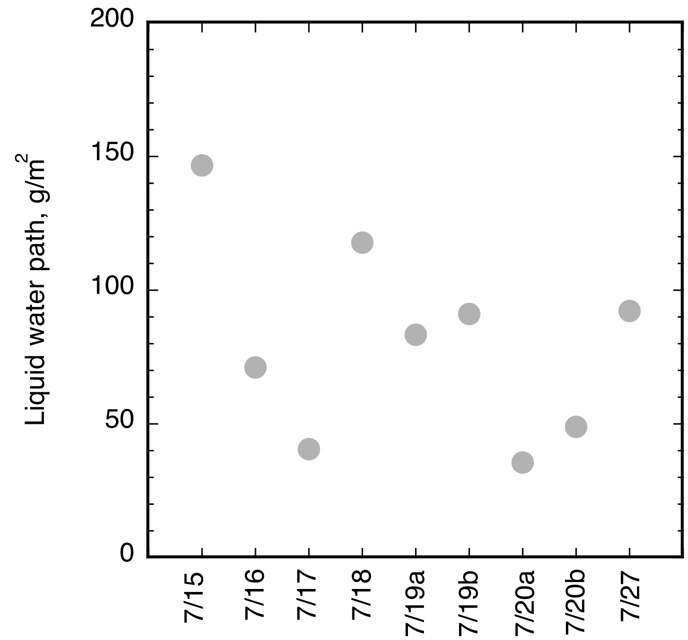
<u>CLOUD PROPERTIES</u>



In all cases, clouds exhibited uniform tops that were bounded by a strong temperature inversion that greatly restricted entrainment of air from aloft.

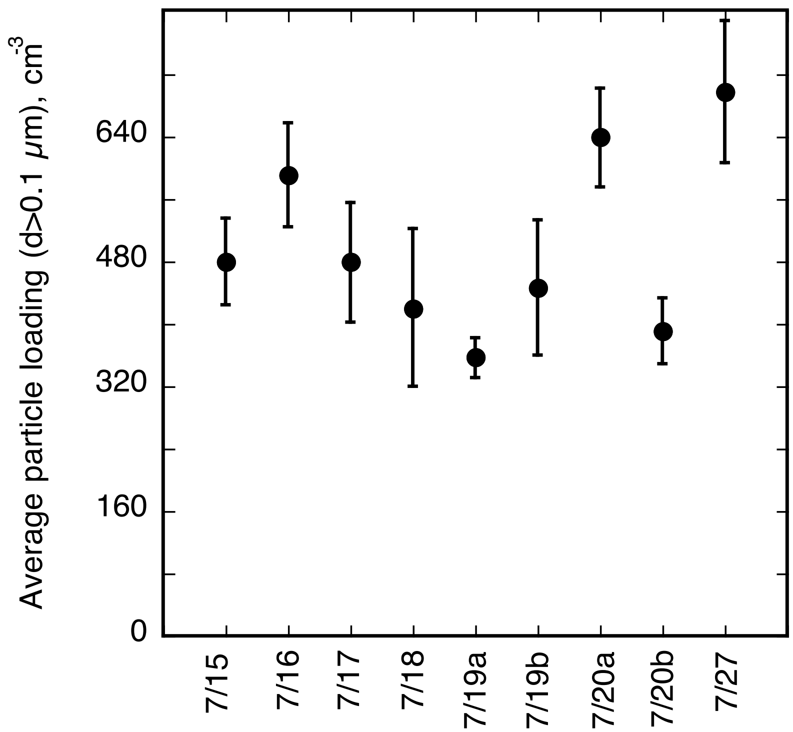
CLOUD THICKNESS AND LIQUID WATER PATH (LWP)

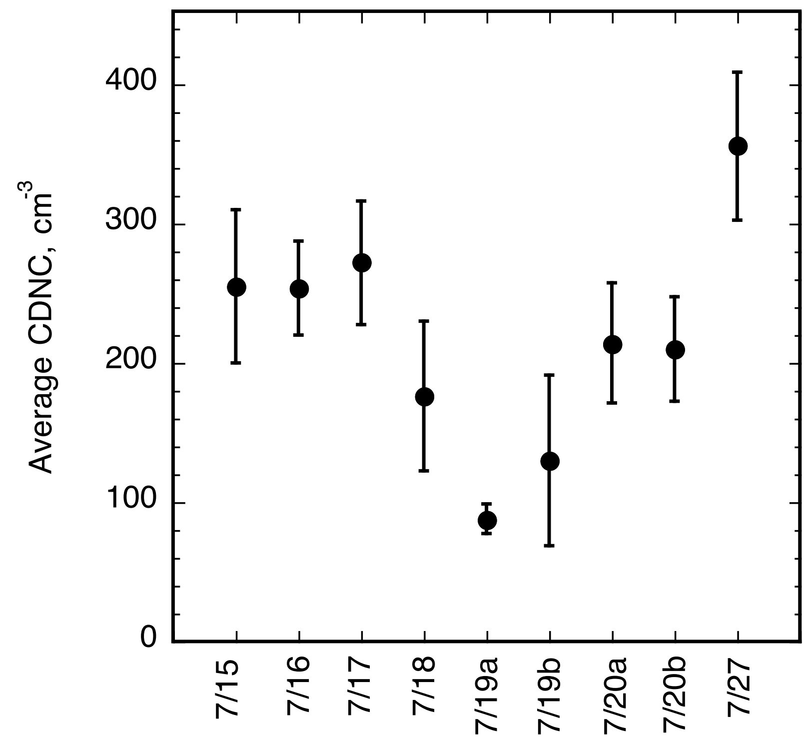




Cloud thickness ranged from about 220 to about 400 m. Liquid water paths ranged from ~30 - ~150 g/m^2. With the exception of 7/15, there was an excellent correlation (r^2=0.94) between cloud depth and LWP.

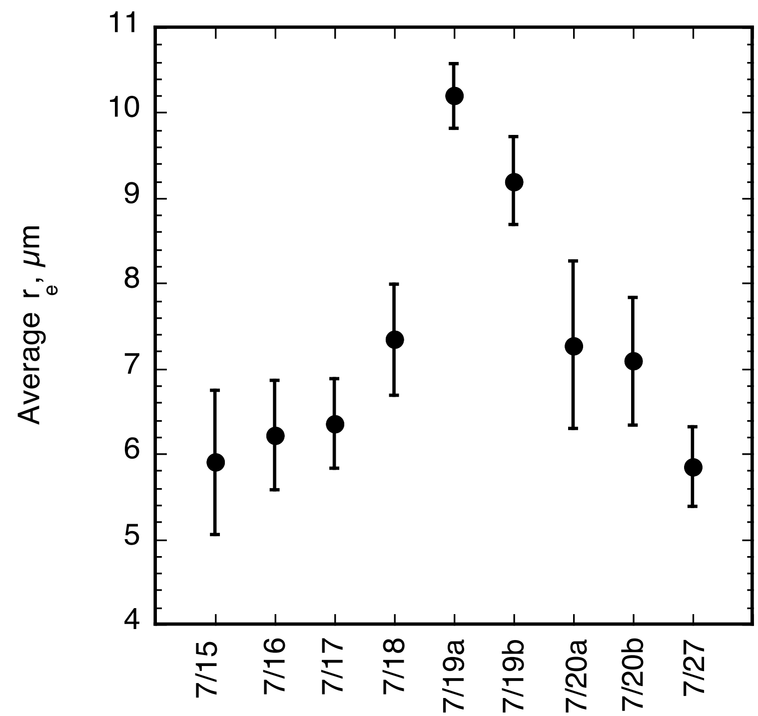
Aerosol and Cloud Droplet Concentrations





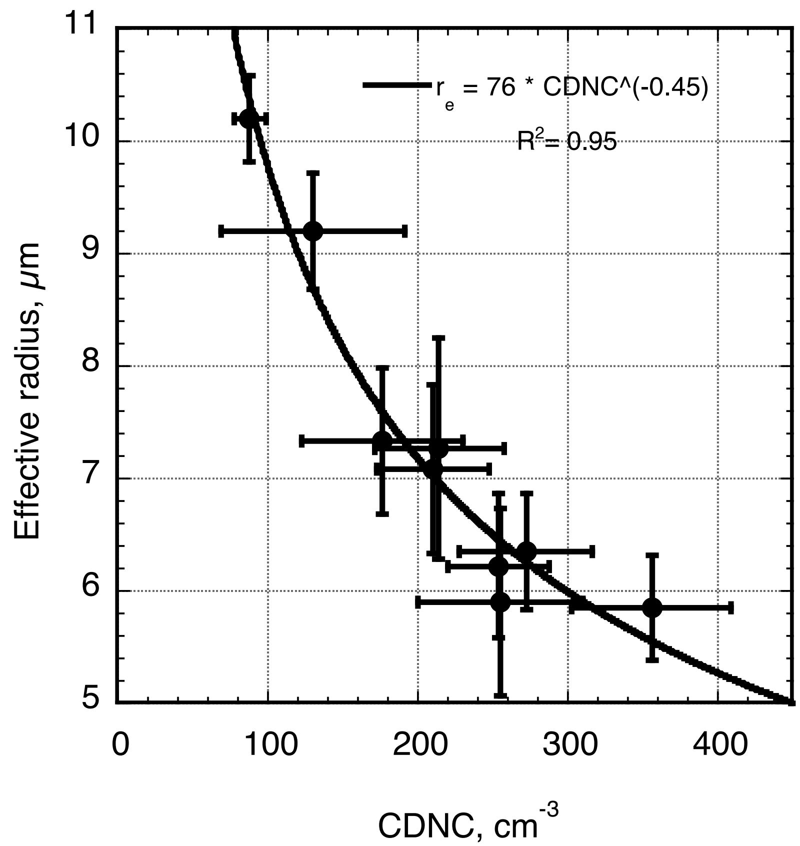
Accumulation mode particle concentrations were high on all days, and this was reflected in the magnitude of the cloud droplet number concentrations. These are not remote marine stratus!

Cloud Droplet Effective Radius (r_E)



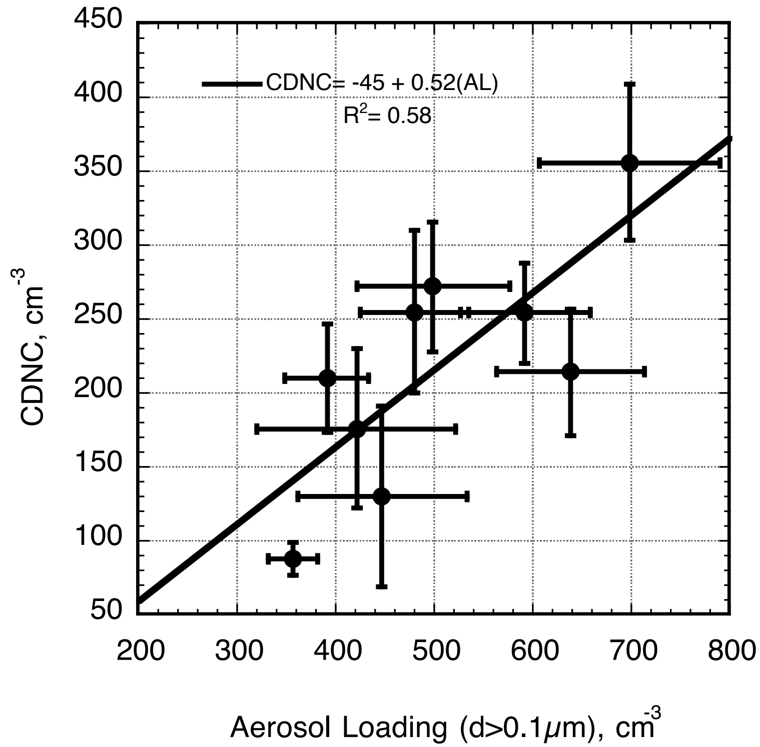
Mean cloud droplet effective radius varied by nearly a factor of 2. On all days, r_e increased with altitude above cloud base due to droplet growth by condensation of water. The variations in r_e were correlated with variations in the CDNC.

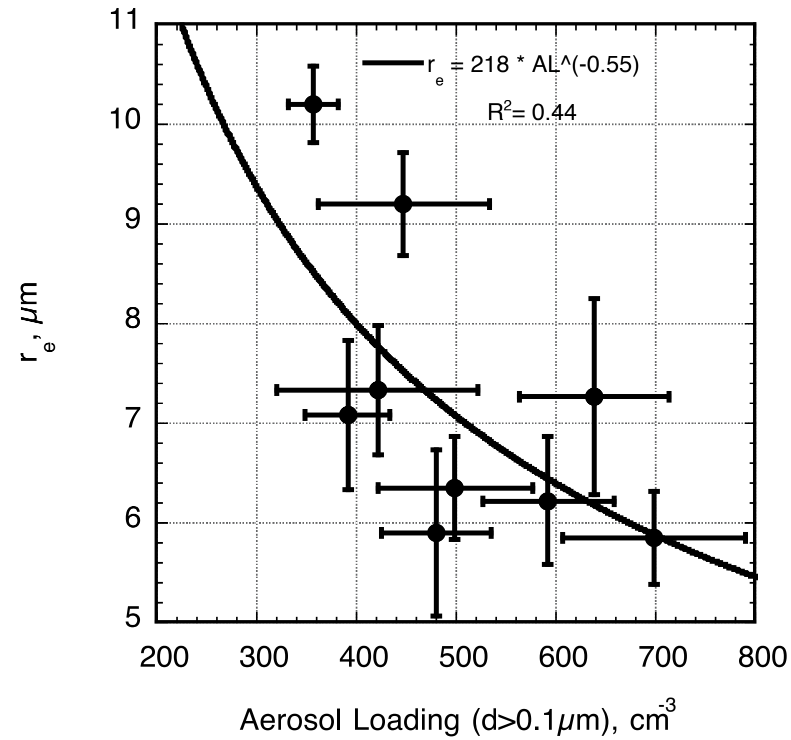
Relationship Between Cloud Droplet Number Concentration, and Size



Cloud depth and LWC were similar for all clouds, so increases in CDNC led to decreases in droplet size.

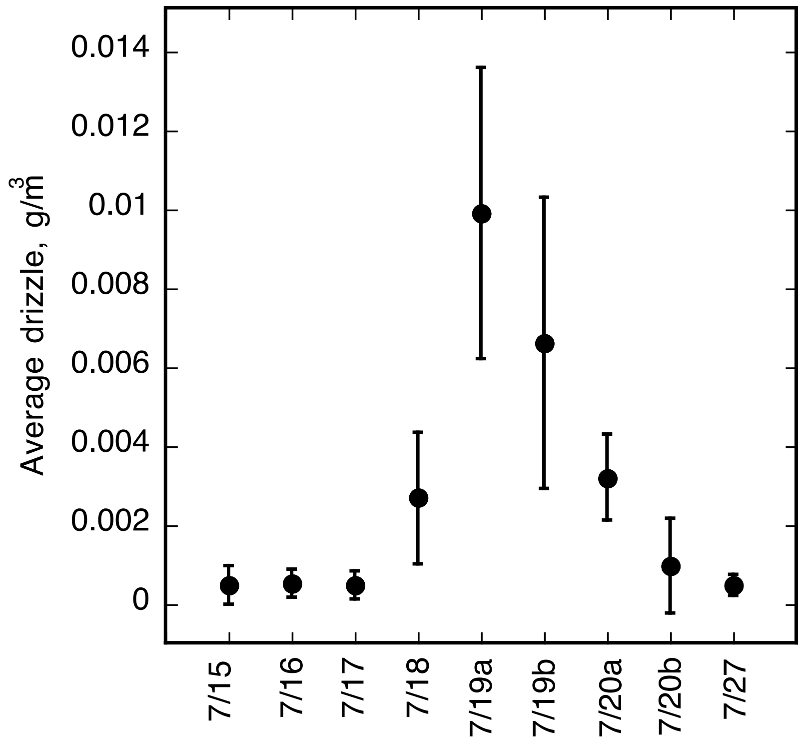
Evidence for the First Indirect Aerosol Effect





Cloud droplet number concentrations increase and the sizes decrease as the accumulation-mode particle loading increases, just as expected.

Drizzle and the Second Indirect Aerosol Effect



Almost all clouds had drizzle (defined as droplets with d >25 μm), but day-to-day amounts differed by nearly a factor of 20. So, why do some clouds drizzle and others not?

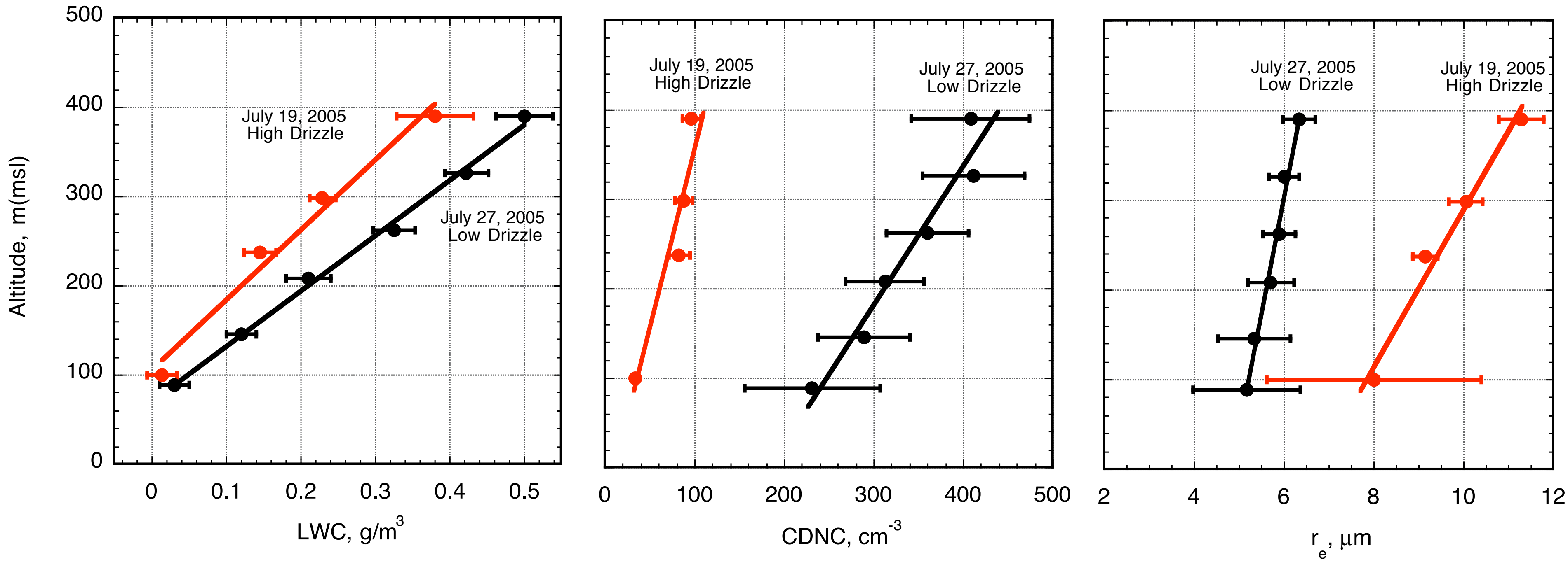
<u>Drizzle Observations</u>

Drizzle water content and drizzle droplet size increased in all cases in going from cloud top to cloud base. This is consistent with the formation of drizzle near cloud top followed by droplet growth through collision processes with cloud droplets as the droplet fall towards the surface.

So why do some clouds have drizzle and others not?

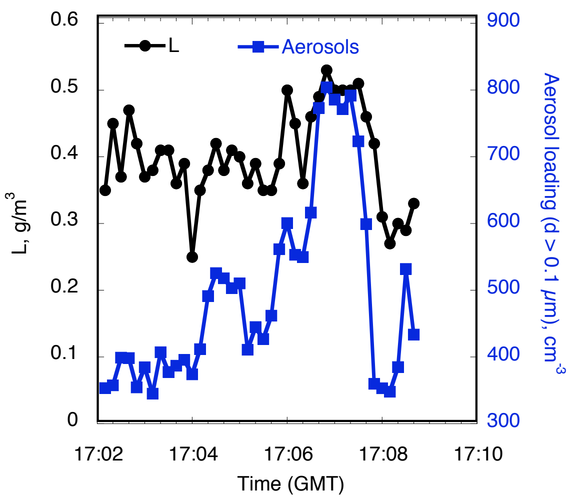
Compare the microphysics of a high drizzle day to a low drizzle day.

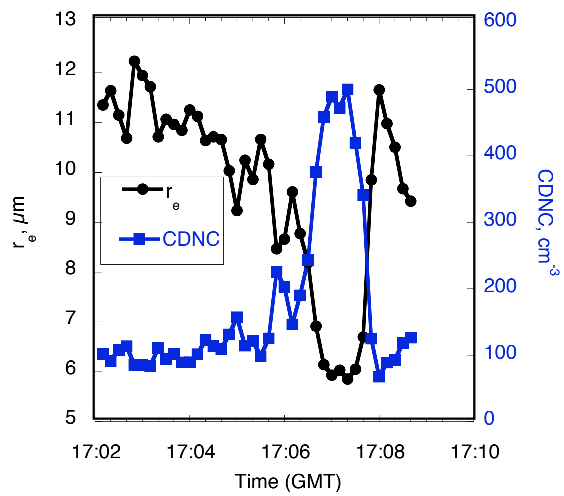
Comparison of High- and Low-Drizzle Microphysics

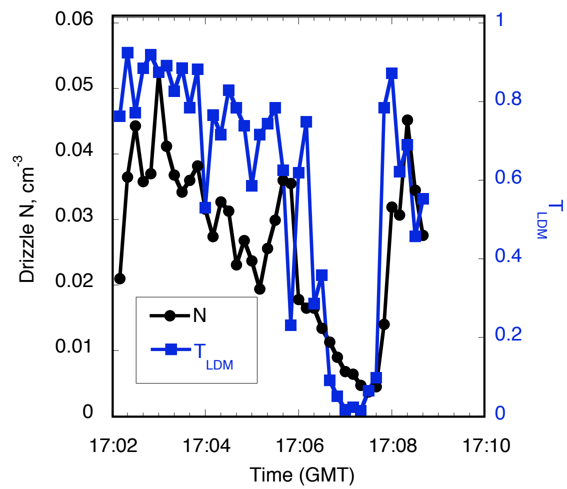


Cloud droplet concentration is smaller and size is larger in the high drizzle cloud than in the low drizzle cloud, although cloud liquid water content is similar.

Drizzle Suppression by an Aerosol Plume

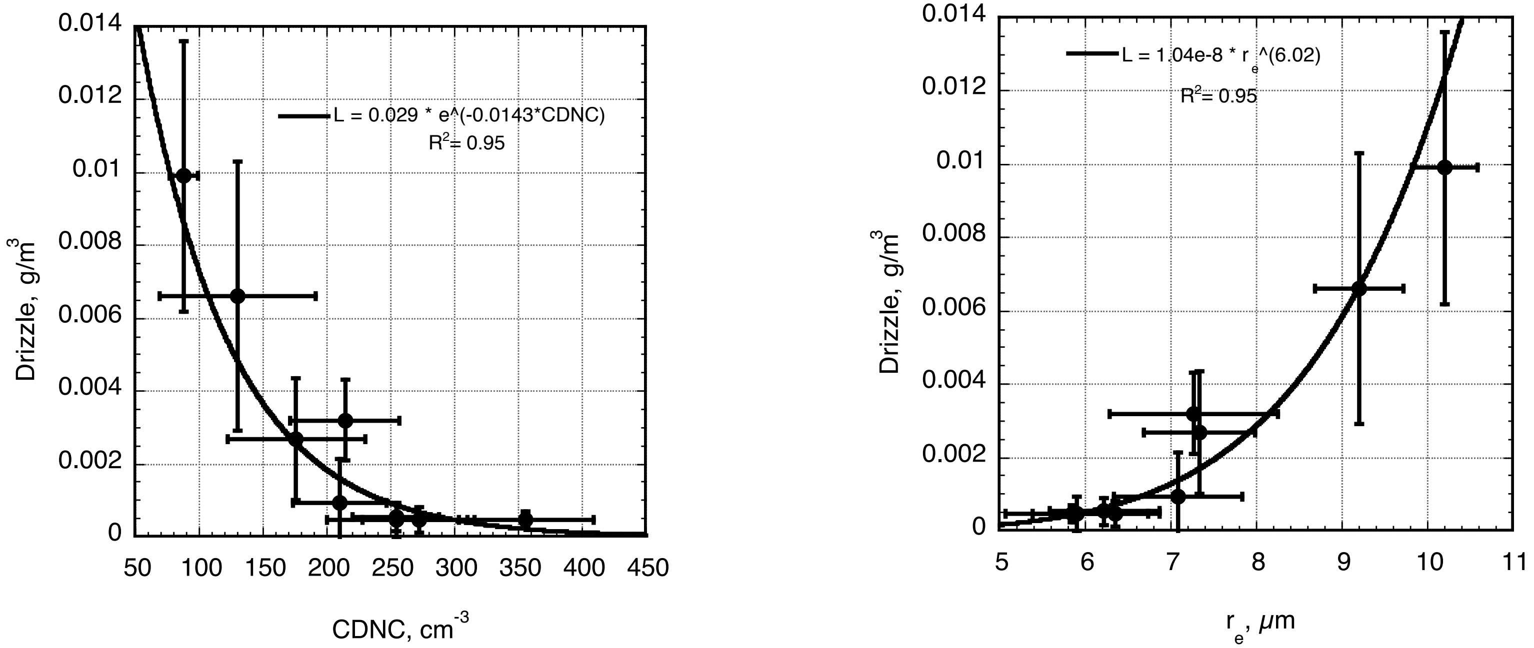






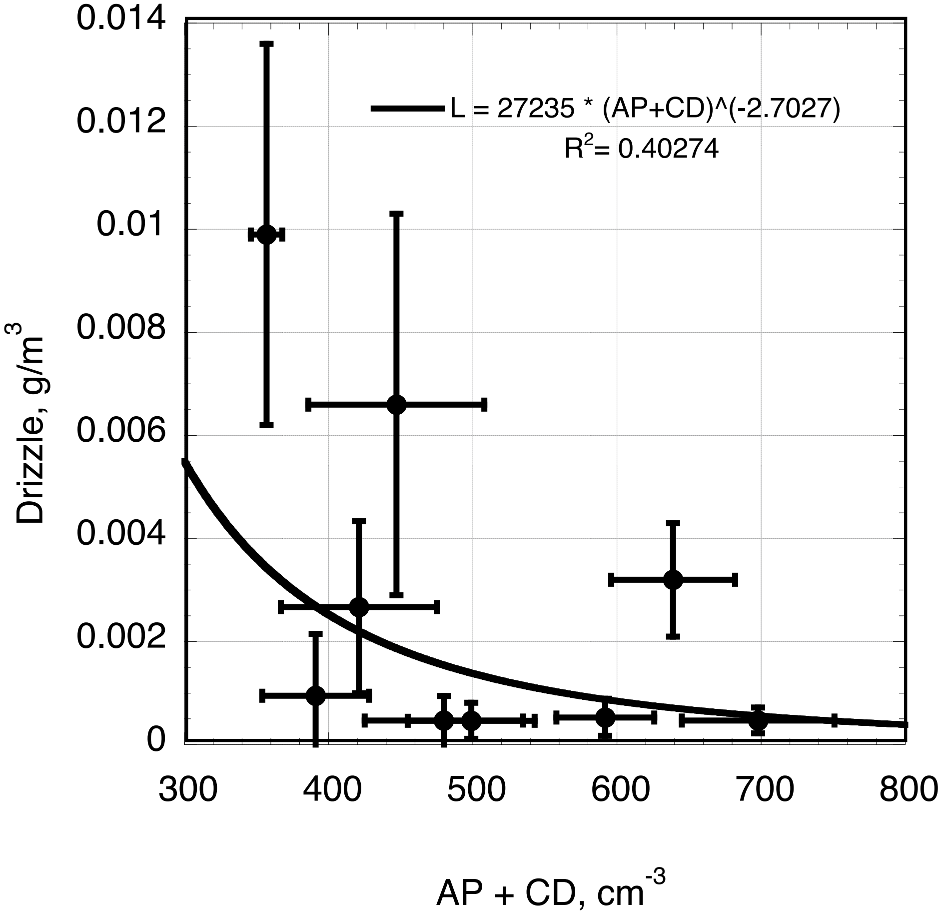
Aerosol plume leads to an increase in the CDNC and a decrease in r_e. This results in a decrease in T_{LDM}, which is a recently derived quantity that describes the onset of the drizzle process (Liu, Daum, McGraw, GRL, 2005), and a nearly complete suppression of drizzle.

Second Indirect Aerosol Effect



Low drizzle water contents are associated with large numbers of small cloud droplets; high drizzle water content associated with fewer numbers of large cloud droplets. Behavior is consistent with the "Second Indirect Aerosol Effect" hypothesis. But how is this related to the aerosol loading?

<u>Second Indirect Aerosol Effect</u>



Suppression of drizzle clearly associated with an increase in the aerosol loading, but relationship is not nearly as robust as the relationship between droplet number concentrations, droplet size, and drizzle.